# Applied Virtual Reality at MSFC

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Application of virtual reality (VR) technology offers much promise to enhance and accelerate the development of space systems infrastructure and operations while simultaneously reducing developmental and operational costs. From control center design analyses to extravehicular activity (EVA) operations development to mission and science training for crew and ground controllers, VR can provide cost-effective methods to prepare for and conduct space flight operations.

A VR applications program has been under development at MSFC since 1989. The objectives of the MSFC VR applications program are to develop, assess, validate, and utilize VR in hardware development, operations development and support, mission operations training and science training.[1] One of the goals of this technology program is to enable specialized human factors analyses earlier in the hardware and operations development process and develop more effective training and mission support systems.[2]

The MSFC VR systems reside in the Computer Applications And Virtual Environments (CAVE) Laboratory. Until recently, the CAVE Lab VR system (the "Legacy VR System") consisted of VPL Research, Inc. Eyephones (Models 1 and LX), DataGloves, and VPL software (Swivel 3D, Body Electric, and ISAAC), Polhemus Isotrak and Fastrak spatial tracking systems, two Macintosh IIfx computers and two Silicon Graphics Inc. (SGI) graphics computers (4D/310VGX and 4D/320VGXB). The CAVE Lab VR capabilities have now been upgraded. Sense8, Inc. WorldToolKit has replaced the VPL software. It runs on an SGI Indigo2 High Impact (250 MHz, 128 MB memory, 4 MB Texture memory, 4 GB disk, impact channel option (ICO)). Other additions include Kaiser Electro-Optics VIM 1000 HRpv and VIM 500 pv head-mounted displays (HMDs), the StereoGraphics Corp. CrystalEyes2 three-dimensional stereo eyeware (two pair of glasses), the Ascension Technology Corp. "Bird" spatial tracking systems (two) and the Crystal River Engineering, Inc. Acoustetron II 3D Sound Server. EXOS, Inc., under a Small Business Innovative Research (SBIR) Phase II contract, developed and delivered a sensing and force-reflecting exoskeleton (SAFiRE) for the hand. This device provides force-reflecting feedback to the fingers and hand as the user touches and grabs virtual objects. Other CAVE laboratory equipment includes SUN Microsystems, Inc. SUNSparc 20 and SUNSparc 10, a Panasonic AG–1960 VCR, and the Videonics MX–1 NTSC digital video mixer.

The development of several VR applications are currently underway. These include:

- Spacelab stowage reconfiguration training: The essential feature of this application is a virtual Spacelab module (VSLM). It involves using this VSLM during the last 6 to 9 months before launch. There are always late changes to on-board stowage. As changes are made, the MSFC Payload Crew Training Complex (PCTC) training mockup is updated. It is desirable to allow the crew the opportunity to tour the mockup to "see" the latest stowage configuration. This helps to "internalize" the location of items within the Spacelab module. Unfortunately, as the launch date approaches, access to the crew becomes increasingly limited, particularly during the last 3 months when the crew is dedicated primarily to the Johnson Space Center (JSC).


**FIGURE 113.—Immersive VR with head-mounted display and DataGlove.**

A VSLM with the updated stowage configuration would enable a more convenient, even remote, method to "visualize" changes in stowage locations. Updated VSLM files could even be electronically transmitted to JSC for the crew to "tour" on the JSC VR system. To further enhance this training application, using both the MSFC and JSC VR systems simultaneously, the users could enter and interact within the same VSLM at the same time, even though they are physically located in different states. This would permit, for example, a mission specialist at JSC to be accompanied by the stowage manager or a payload specialist at MSFC for the stowage "walk-thru."

The pathfinder Spacelab for this VR application is the second International Microgravity Lab (IML–2). A VSLM with two "stocked" lockers has been developed along with application-unique kinematic and object behavior attributes.

Modeling and functional evaluation on the Legacy VR System is complete. Porting to the new VR system and further enhancements (including expanded functionality, texture mapped photos from the PCTC mockups, etc.) are planned. Analog empirical studies as well as crew and Payload Operations Control Center (POCC) cadre assessments are proposed. Evolution to the *International Space Station (ISS)* U.S. lab element is proposed.

- VR human anatomy teaching: The objectives of this project are to develop, evaluate, and utilize a VR application of a human cadaver for use in the classroom. The expectation is that this immersive learning environment affords quicker anatomic recognition and orientation and a greater level of retention in human anatomy instruction. This is a pathfinder for developing and assessing VR applications to be used for science training. A unique feature of this project is that the target platform must be inexpensive enough to be affordably placed in the classroom (currently a Pentium-based PC). A "virtual cadaver" with abdomino-pelvic organs is being developed.

Modeling and functional evaluation on the Legacy VR System is complete. Portage to WorldToolKit for Windows and Pentium PC is complete. In the coming year, more organs and a skeleton will be added to the model. Three-dimensional sound will be added to the major organs. An empirical study comparing the learning of gross anatomy in the VR human cadaver versus the current method of instruction will also occur during the coming year. Assessments will include whether the students learned faster, gained a deeper level of understanding, and/or had longer retention. In subsequent years, more detail (subdivided organs, texture mapping, etc.) and networking will be added. Teaching efficacy will continue to be empirically assessed.

- International Space Welding Experiment (ISWE) analytical tool and trainer: The objectives of this project are to develop, evaluate, and utilize a VR application of the ISWE for use in support of upcoming Neutral Buoyancy Simulator (NBS) tests and in training the flight crew and POCC cadre in general orientation, procedures, and location, orientation, and sequencing of the welding samples and tools. Since some of the hardware and operational analyses have already occurred in the NBS, ISWE will serve as a test case for this technology. Analytical results from the NBS and VR can be compared. The ISWE is a cooperative venture between the Paton Welding Institute of the Ukraine and MSFC. It will involve the use of an existing Ukrainian electron beam welder to be located in the cargo

**FIGURE 114.—Sensing and force-reflecting exoskeleton (SAFiRE) in action. International Space Welding Experiment (ISWE) on monitor.**

bay of the orbiter. The ISWE is planed for flight as an element of the fourth United States Microgravity Payload Mission (USMP–4), currently scheduled for October 1997.

- Teleoperations using virtual reality: The *ISS* modules will be linked together using devices known as "common berthing mechanisms" (CBM's), the mating portions of which must be aligned within plus-or-minus 1 in and plus-or-minus one half-degree on each axis prior to activation of the automatic closure latches which draw the two station elements together. In the current design, positioning of the elements is performed by either the Shuttle or Station RMS (remote manipulator system) under man-in-the-loop control from on board the Shuttle nor Station. Unfortunately, neither a direct or video view of the berthing interface from useful vantage points is available in most scenarios.

  This project proposes an alternative control scheme which involves replacement of the boresight camera with a precision video alignment sensor (already developed for autonomous rendezvous and docking), which would provide the CBM relative position and attitude data to a real-time computer graphics system generating stereoscopic views of the mechanisms and their surroundings. These views would be presented to the operator using a head-coupled head-mounted display, creating a sense of visual presence in the manipulator workspace. The operator will thus be able to see the mechanisms depicted from any useful vantage point desired simply by navigating to and looking in that relative direction. RMS handcontrollers have been integrated with the CAVE Laboratory VR system and linked with a high-fidelity simulation of the Shuttle RMS performing Space Station element berthing. Further refinements and tests are planned.

Several future VR applications are being planned. These include:

- A microgravity science glovebox (MSG) analytical tool for use in training the flight crew and POCC cadre in general orientation and procedures, as well as for use in design analyses and operations development; and

- Further development and assessment of the use of immersive VR for *ISS* payload training for the flight crew and POIC cadre. Of particular interest is the capability of remote, multiperson, interactive simulations and the ease with which training simulators can be reconfigured to support increment-specific integrated training. This activity plans to make advances in four classes of payload training for the flight crew and POIC cadre. These classes are: Payload systems, facility systems, element spatial orientation and stowage configuration, and science education.

[1]Hale, J.P.: "Marshall Space Flight Center's Virtual Reality Applications Program". In Proceedings, 1993 Conference on Intelligent Computer-Aided Training and Virtual Environment Technology, pp. 271–276, NASA, Lyndon B. Johnson Space Center, Houston, TX, 1993a.

[2]Hale, J.P.: "Virtual Reality as a Human Factors Design Analysis Tool". In Proceedings, Southeastern Simulation Conference, pp. 140–144, Huntsville, AL, 1993b.

[3]Null, C.H. and Jenkins, J.P. (Eds.): NASA virtual environment research, applications, and technology. NASA, 1993.

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**Biographical Sketch:** Joe Hale is team leader of the Human Engineering and Analysis Team in the Mission Operations Laboratory. He received a B.A. in psychology from the University of Virginia in 1976, an M.S. in applied behavior science (psychology) from Virginia Tech in 1981, and an M.S. in systems management from the Florida Institute of Technology in 1990. He developed and currently directs the MSFC Computer Applications And Virtual Environments (CAVE) Laboratory which includes the MSFC immersive virtual reality laboratory and test-bed. Hale is also a certified human factors professional (CHFP) (Board of Certification in Professional Ergonomics).